Computer Science
UNIVERSITY OF TORONTO

lecture 2: software architecture

csc302h

winter 2014

administrative

- assignment 1 out this week
- (initial) groups posted to website
  - still without a group? see me at the end
  - see paper on “hitchhikers”
- anyone with prerequisite issues please see me at the end of today’s lecture.
- anyone not officially enrolled please see me

recap from last time

- we build models to help:
  - during design
  - to analyze existing systems (reverse engineer)
  - to help us communicate
- models are abstractions
  - help us focus on important aspects, not blinded by the details
  - decomposition, modularization, association
- introduced some uml
- modeling: we do it all the time…sometimes too much of a good thing

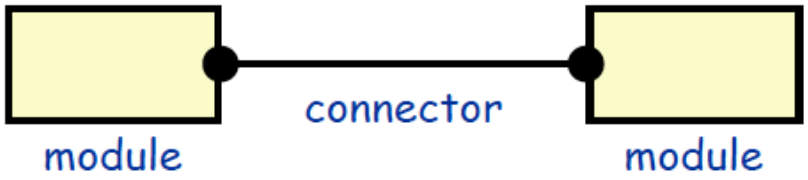
software architecture

Showing the architecture

- → Coupling and Cohesion
- → UML Package Diagrams
- → Software Architectural Styles:
  - Layered Architectures
  - Pipe-and-filter
  - Object Oriented Architecture
  - Implicit Invocation
  - Repositories

Coupling and Cohesion

Architectural Building blocks:



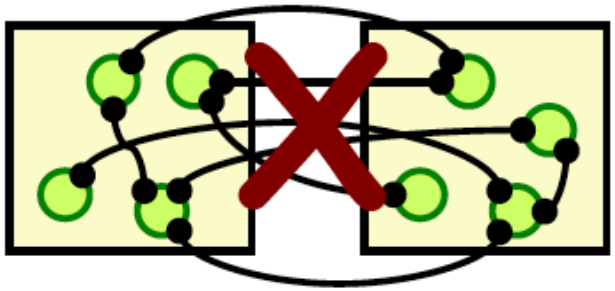
A good architecture:

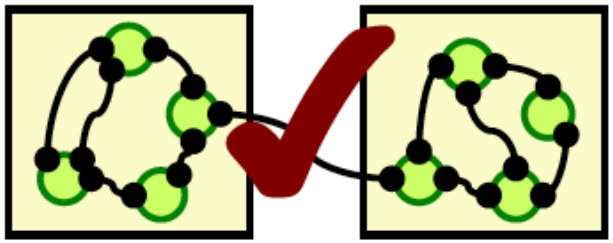
Minimizes coupling between modules:

- Goal: modules don't need to know much about one another to interact
- Low coupling makes future change easier

Maximizes the cohesion of each module

- Goal: the contents of each module are strongly inter-related
- High cohesion means the subcomponents really do belong together

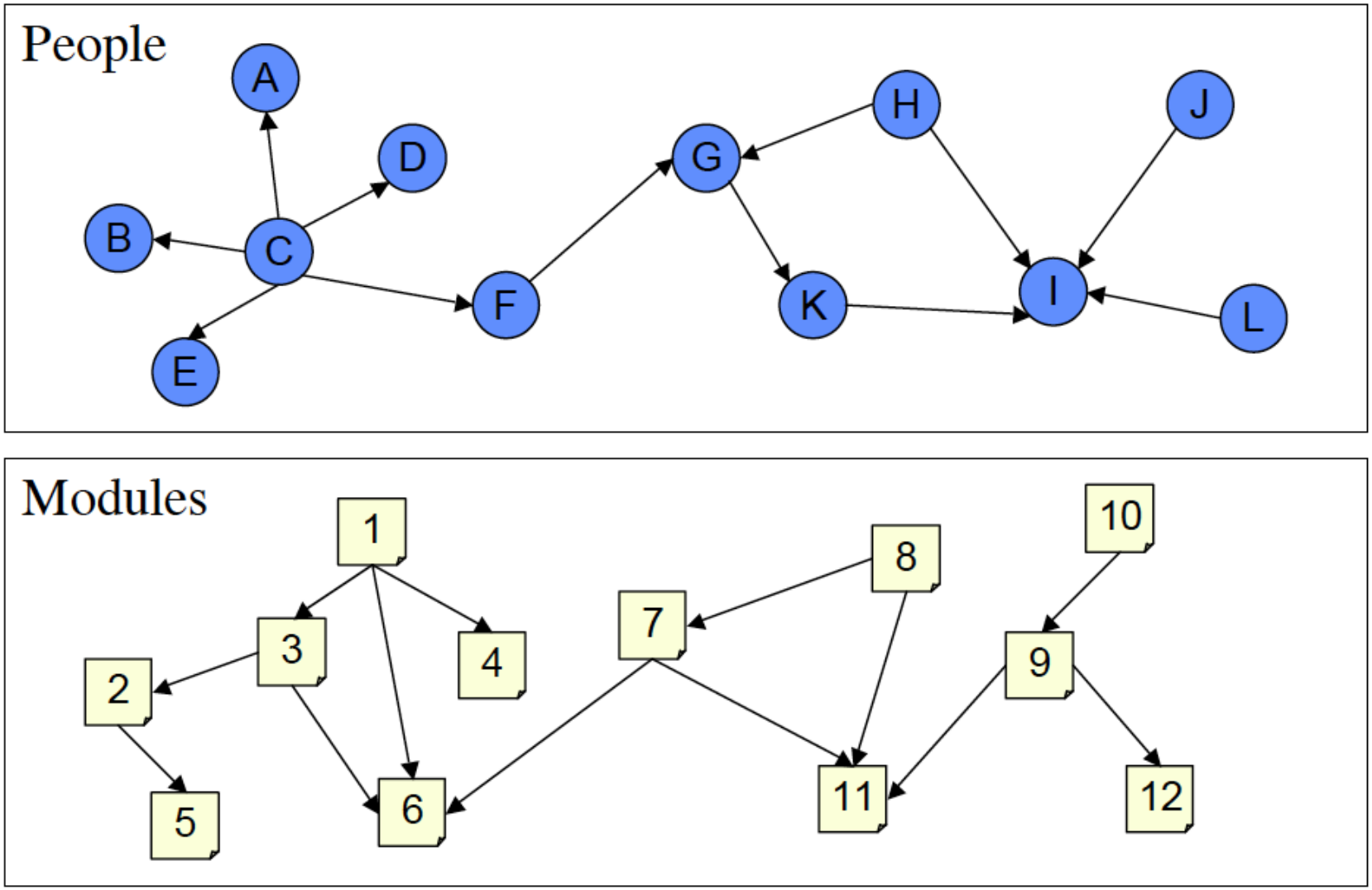




Conway's Law

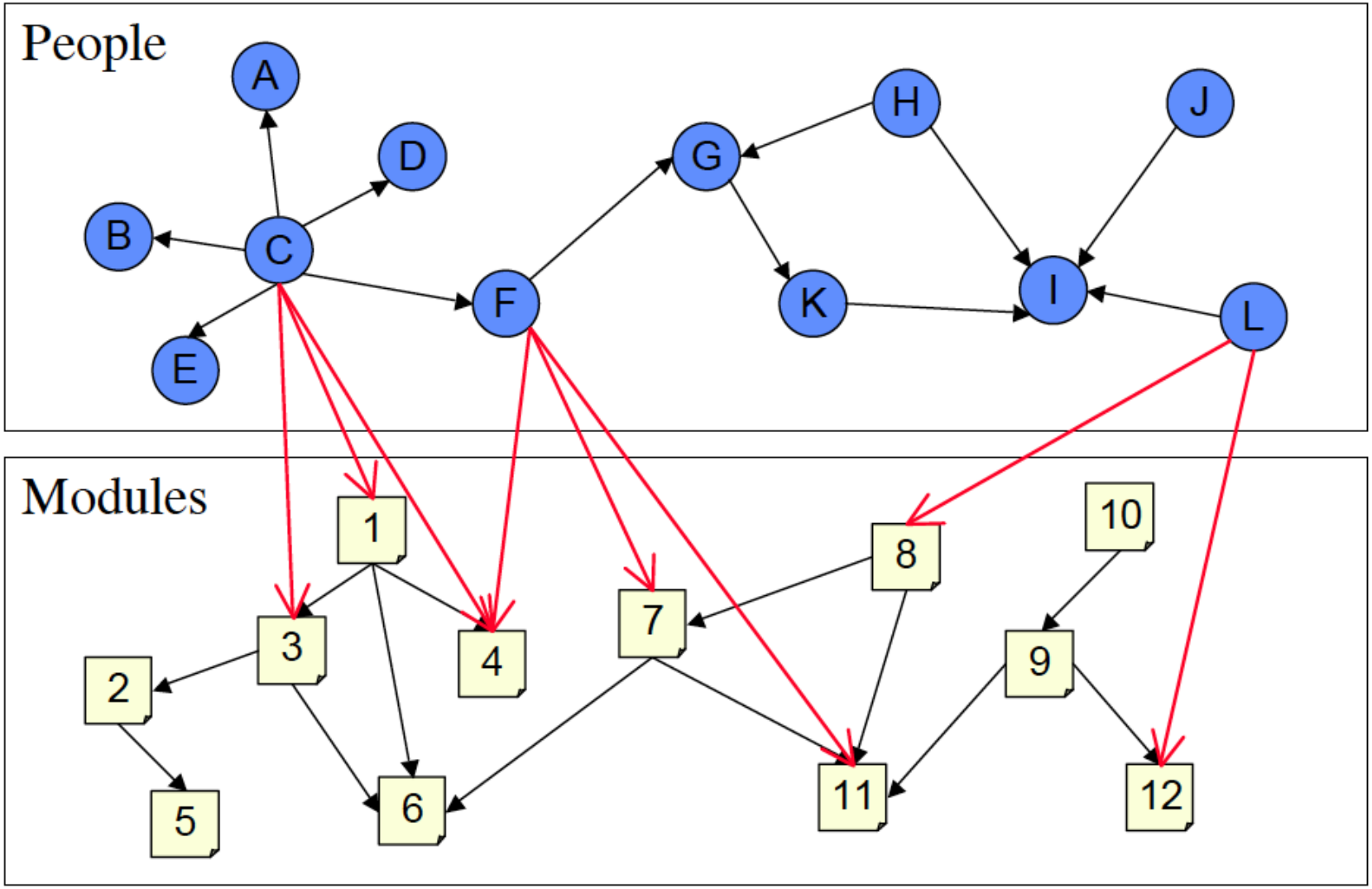
"The structure of a software system reflects the structure of the organisation that built it"

Socio-Technical Congruence



See: Valetto, et al., 2007.

Socio-Technical Congruence



See: Valetto, et al., 2007.

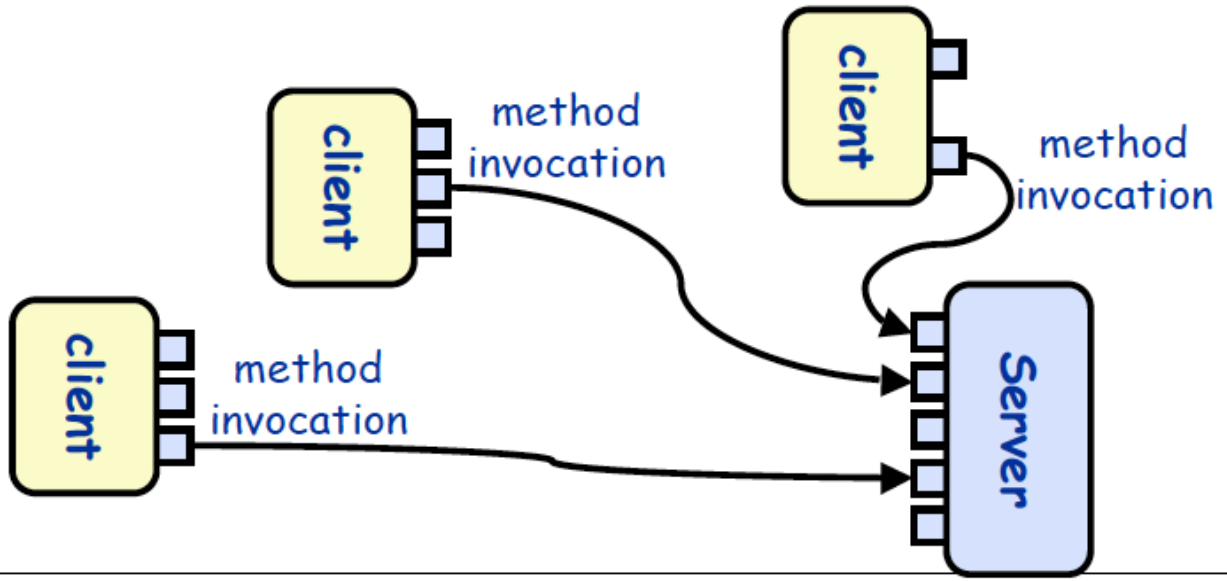
Software Architecture

A software architecture defines:

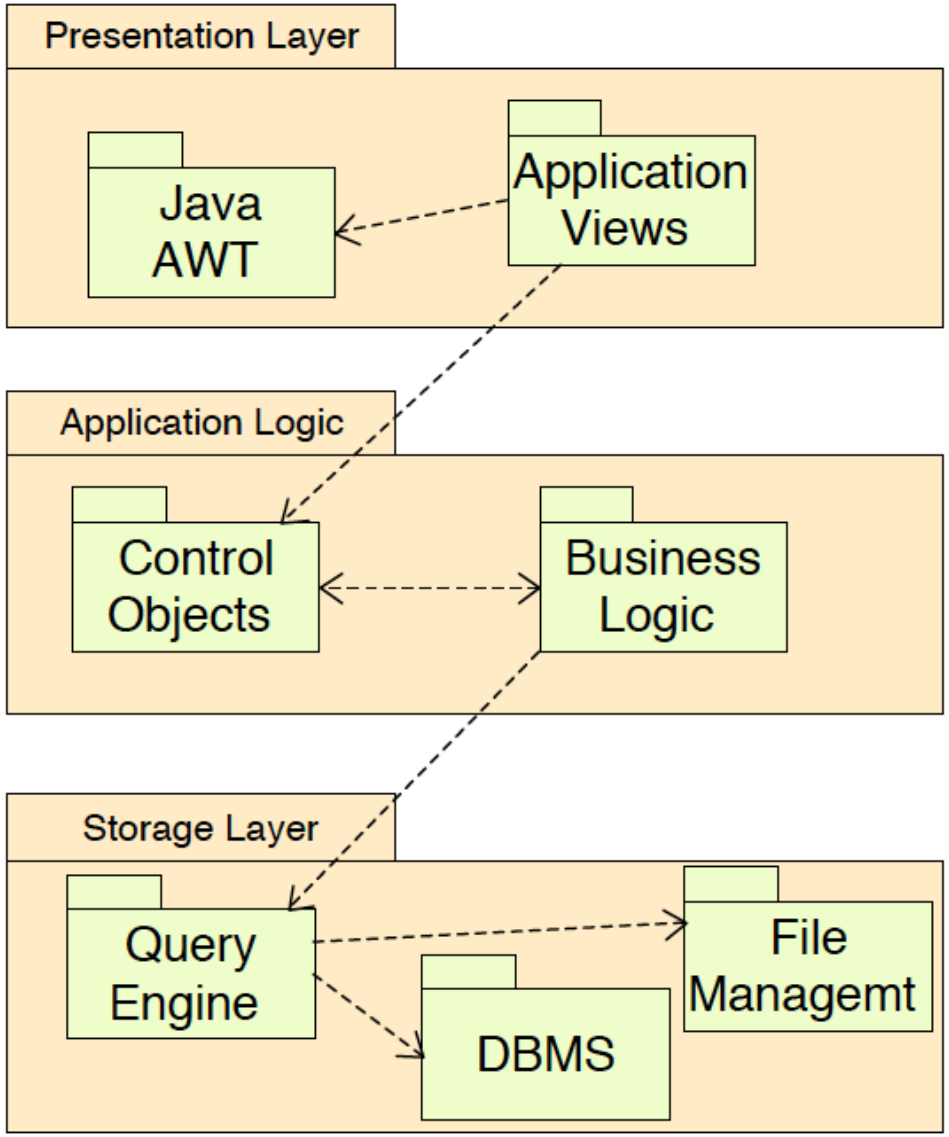
- The components of the software system
- How the components use each other's functionality and data
- How control is managed between the components

An example: client-server

- Servers provide some kind of service; clients request and use services
- Reduced coupling: servers don't need to know what clients are out there



Example: 3-layer architecture



UML Packages

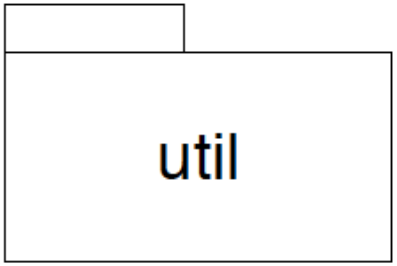
We need to represent our architectures

- UML elements can be grouped together in packages
- Elements of a package may be:
  - other packages (representing subsystems or modules);
  - classes;
  - models (e.g. use case models, interaction diagrams, statechart diagrams, etc)
- Each element of a UML model is owned by a single package

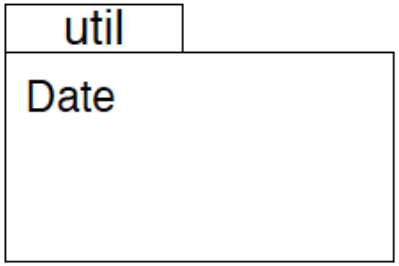
Criteria for decomposing a system into packages:

- Different owners
  - who is responsible for working on which diagrams?
- Different applications
  - each problem has its own obvious partitions;
- Clusters of classes with strong cohesion
  - e.g., course, course description, instructor, student,…
- Or: use an architectural pattern to help find a suitable decomposition…

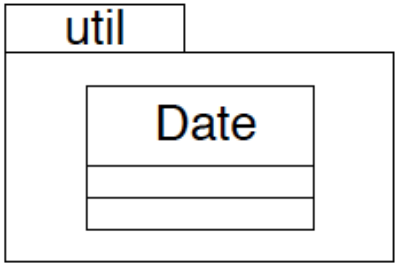
Package notation



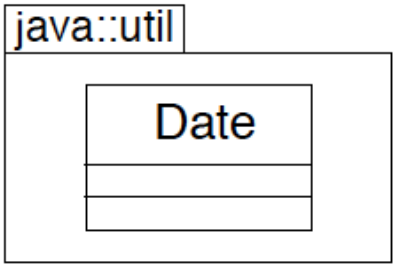
named package



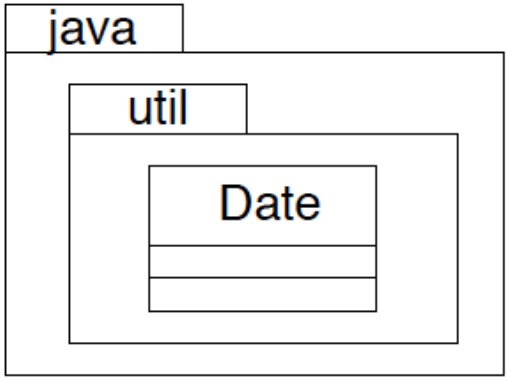
package with list of contained classes



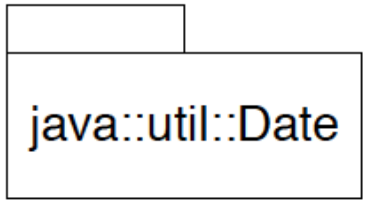
package containing a class diagram



package with qualified name

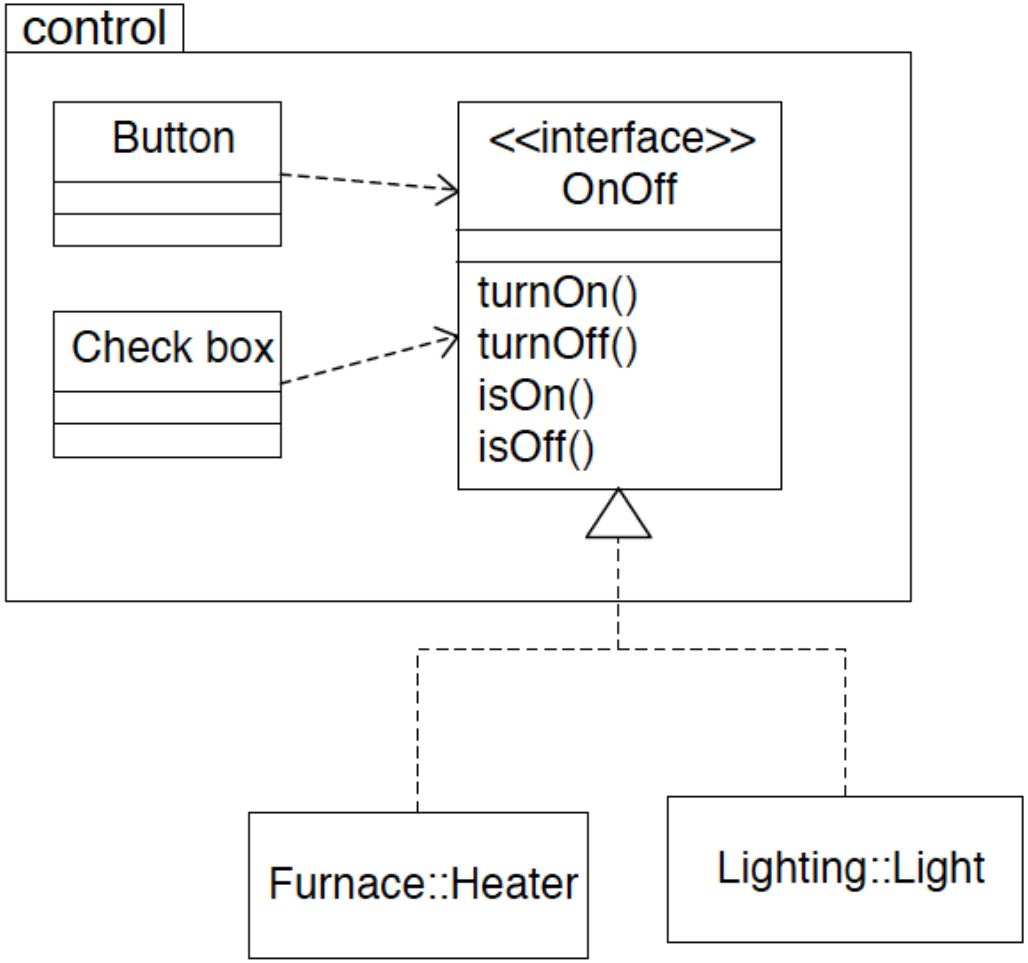


nested packages

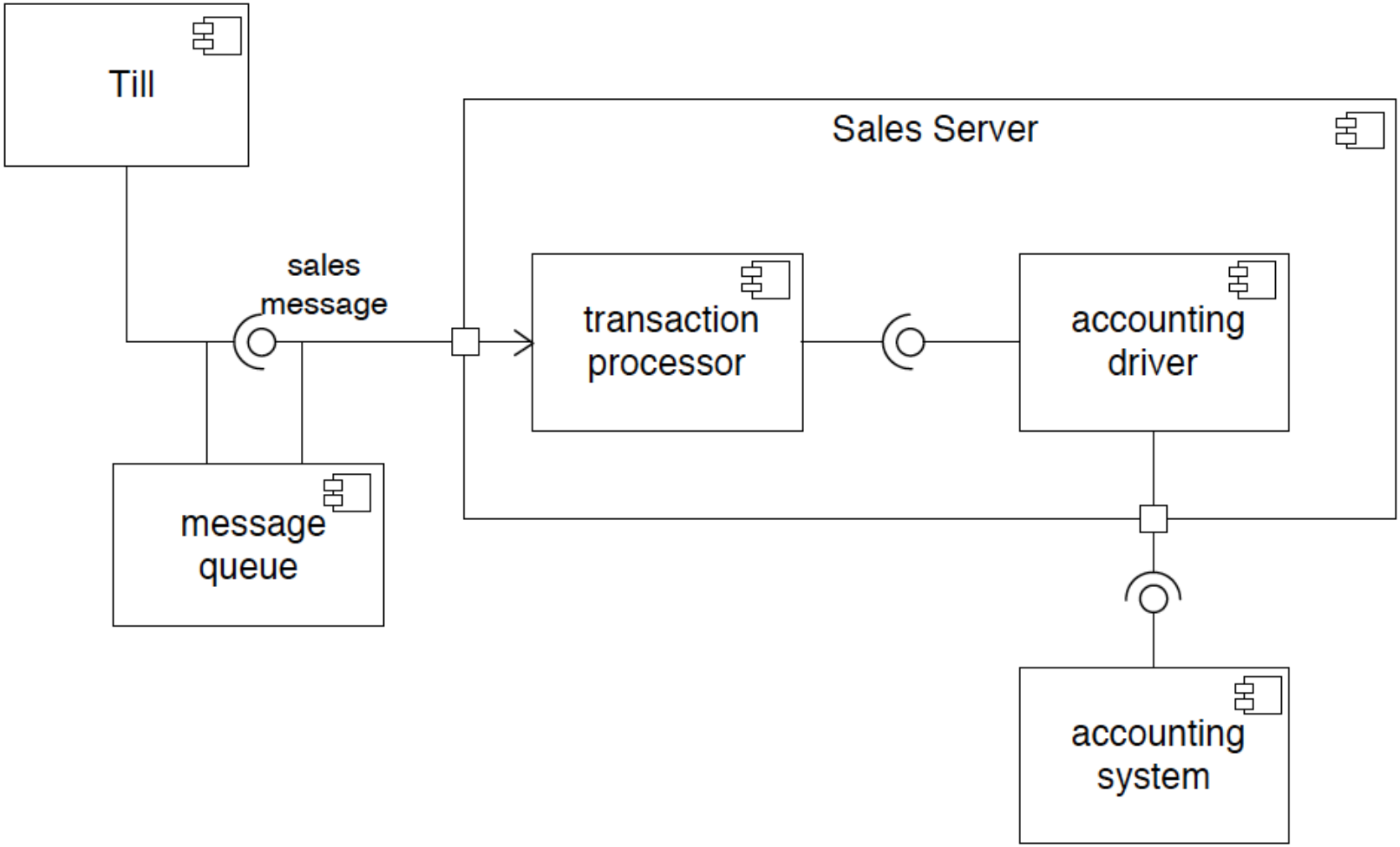


package with fully qualified name

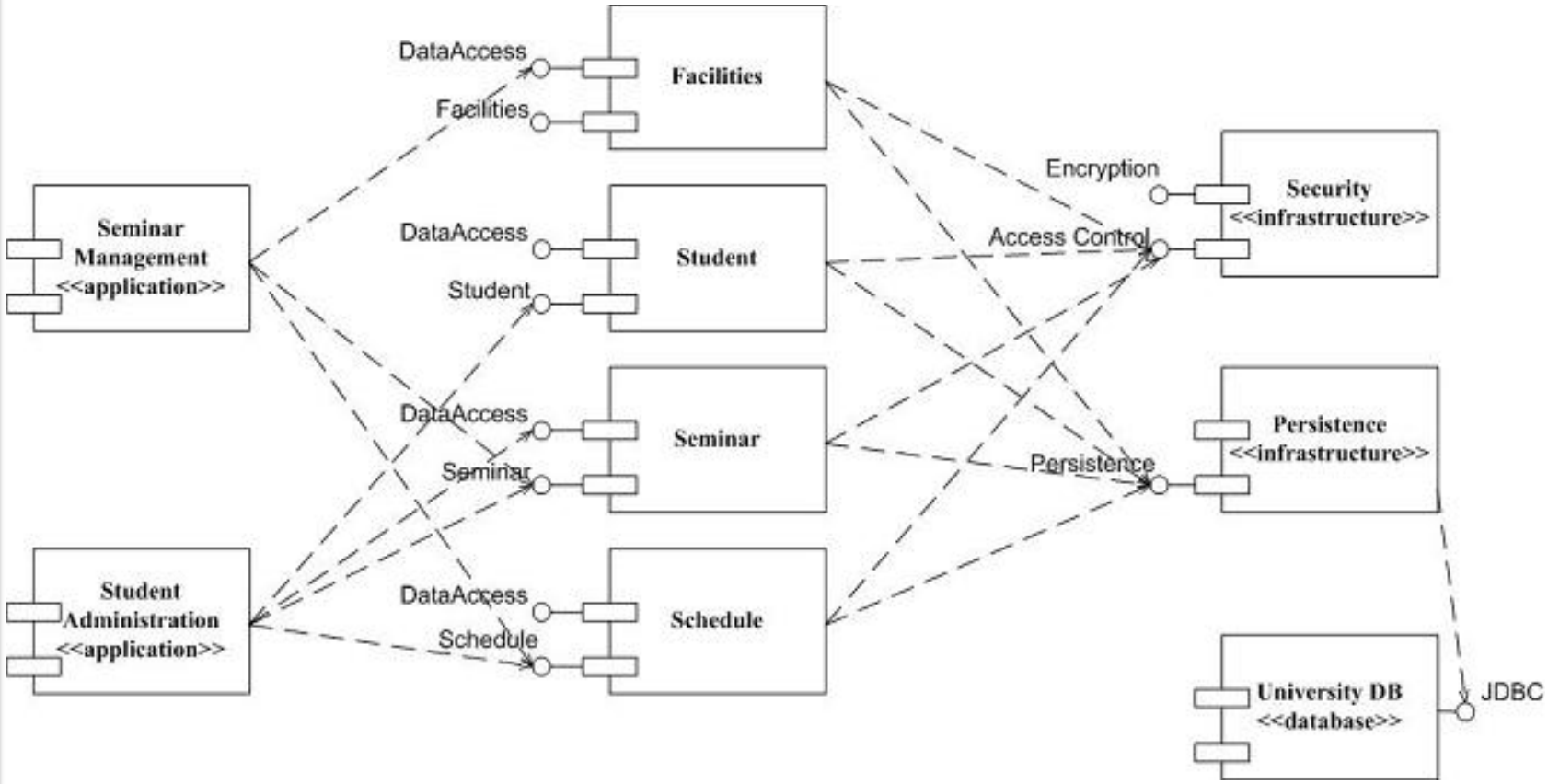
Towards component-based design



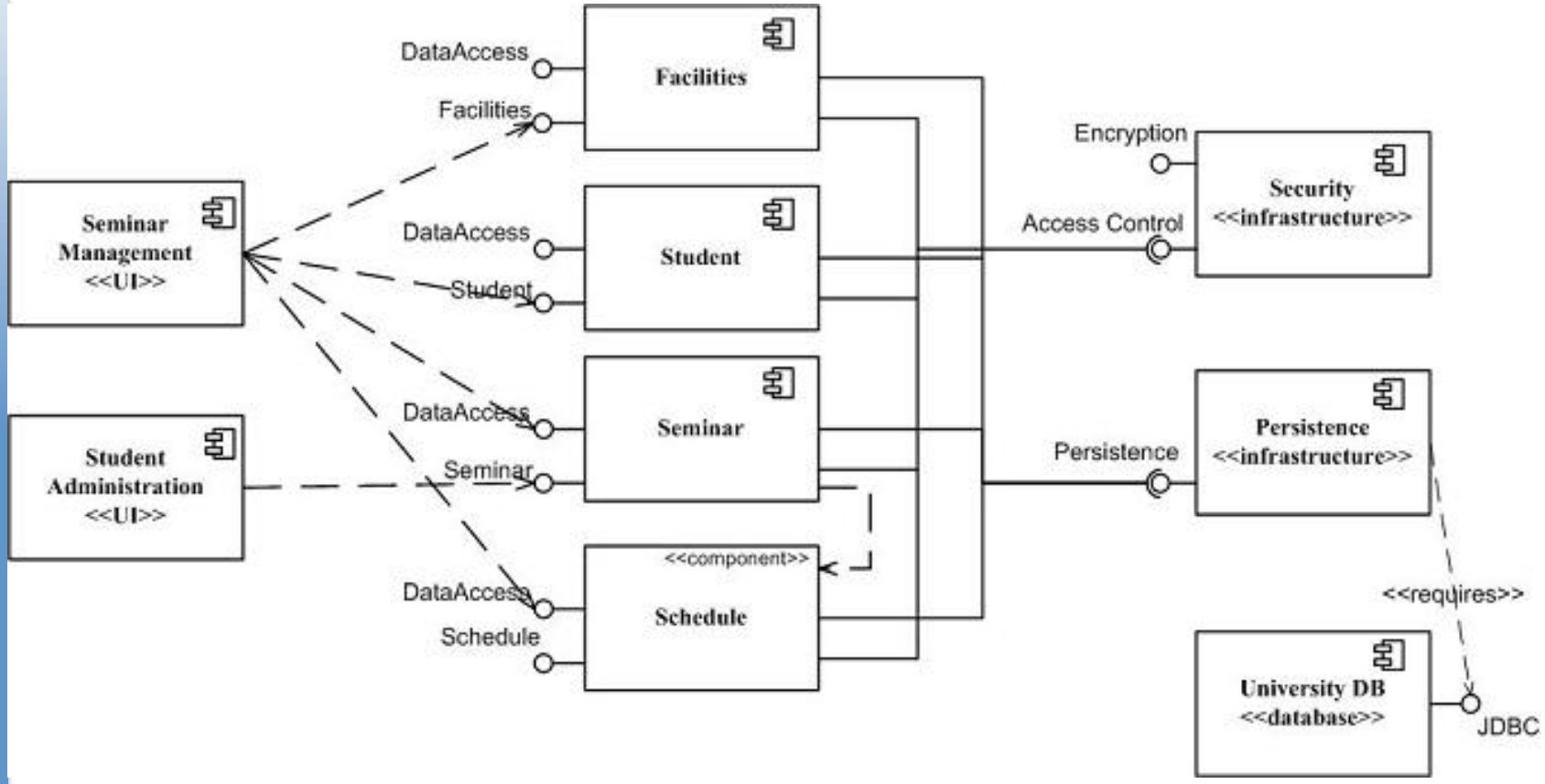
Or use Component Diagrams…



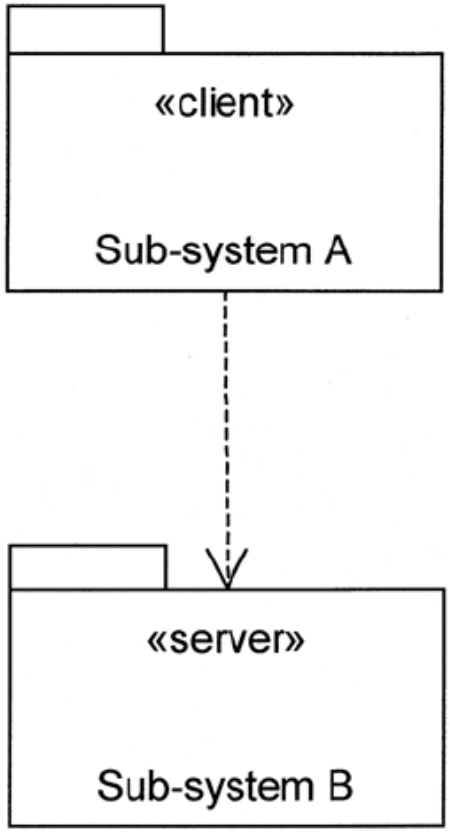
uml 1.0 component diagram



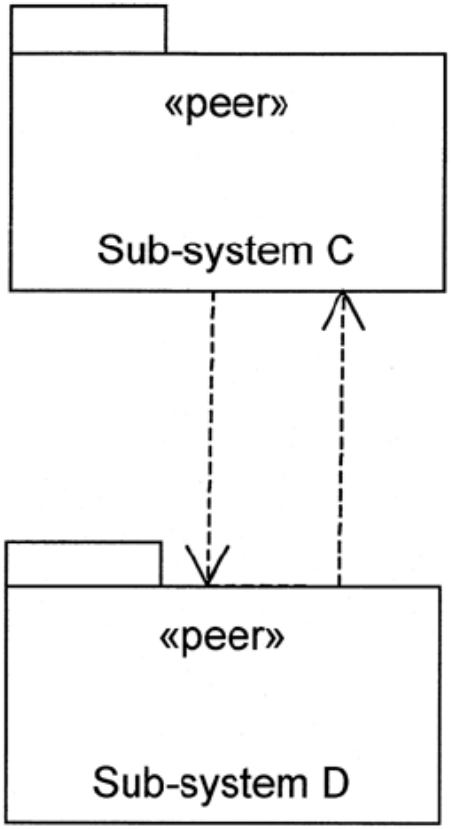
uml 2.0 component diagram



Dependency cycles (to be avoided)



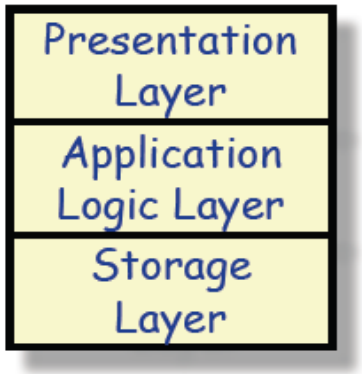
The server sub-system does not depend on the client sub-system and is not affected by changes to the client's interface.

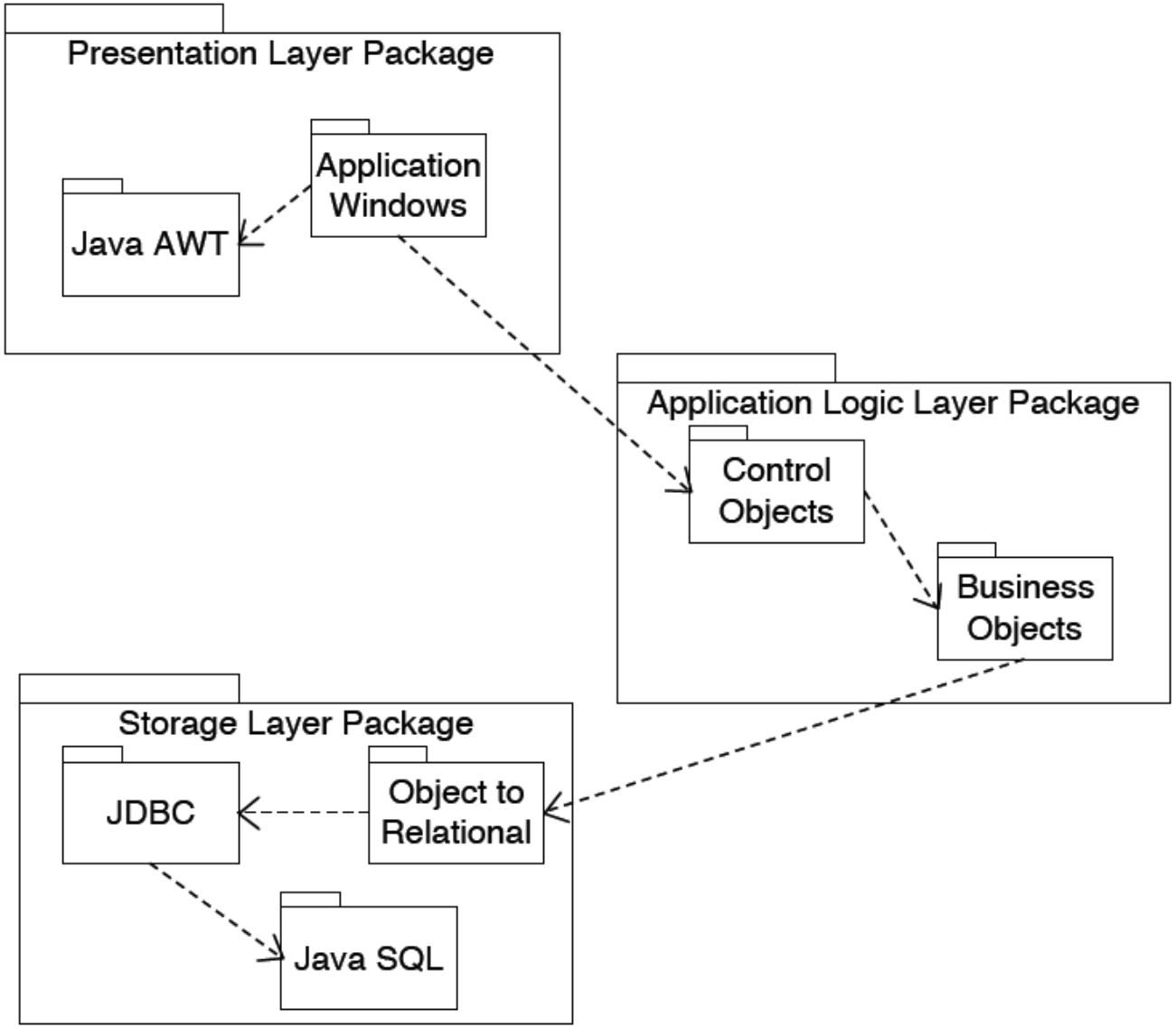


Each peer sub-system depends on the other and each is affected by changes in the other's interface.

Architectural Patterns

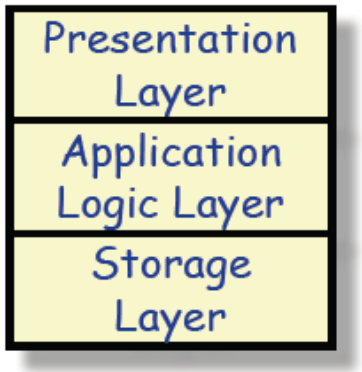
E.g. 3 layer architecture:

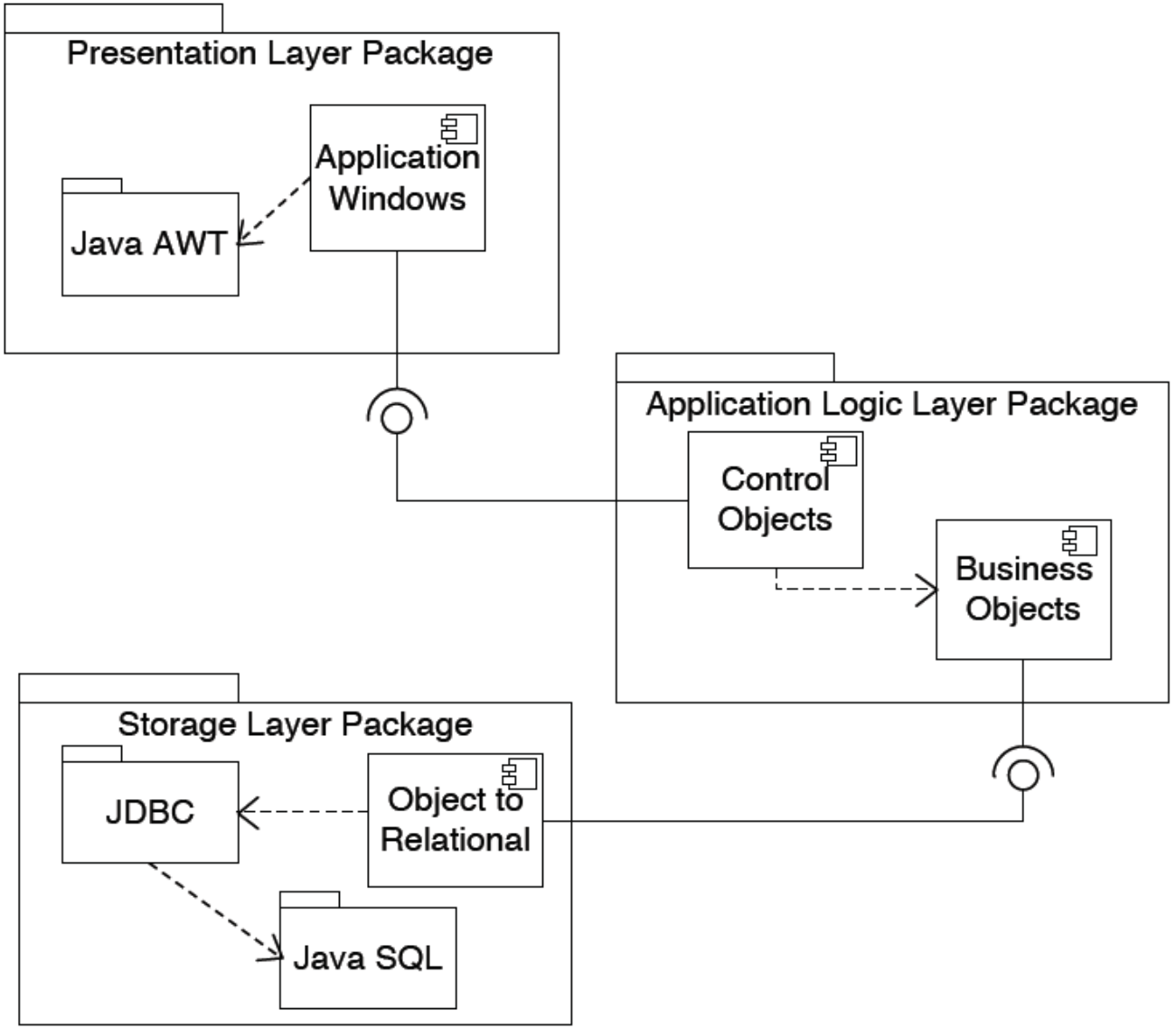




Or to show the interfaces…

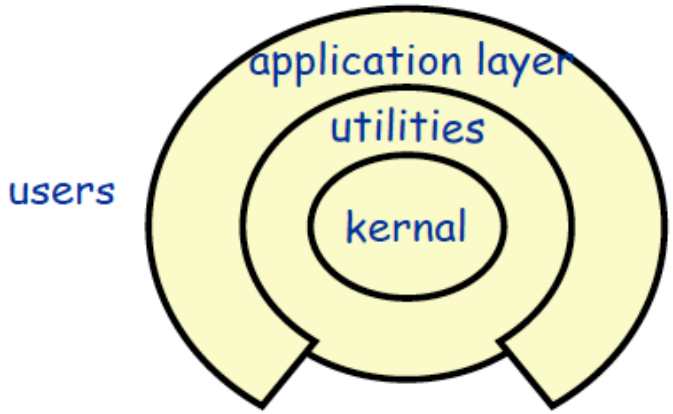
E.g. 3 layer architecture:





Layered Systems

Source: Adapted from Shaw & Garlan 1996, p25. See also van Vliet, 1999, p281.



Examples

- Operating Systems
- communication protocols

Interesting properties

- Support increasing levels of abstraction during design
- Support enhancement (add functionality) and re-use
- can define standard layer interfaces

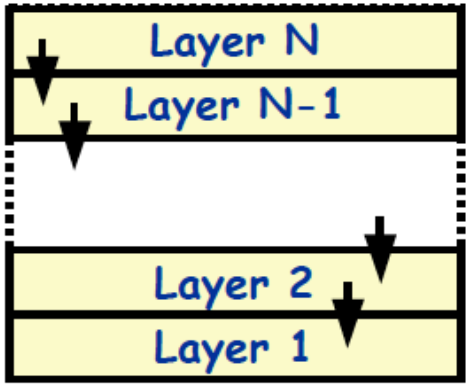
Disadvantages

- May not be able to identify (clean) layers

Open vs. Closed Layered Architecture

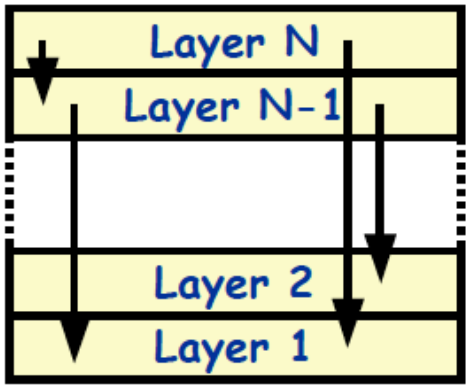
closed architecture

- Each layer only uses services of the layer immediately below;
- Minimizes dependencies between layers and reduces the impact of a change.



open architecture

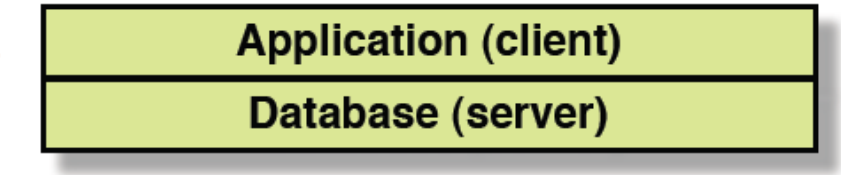
- A layer can use services from any lower layer.
- More compact code, as the services of lower layers can be accessed directly
- Breaks the encapsulation of layers, so increase dependencies between layers



How many layers?

2-layers:

- application layer
- database layer
- e.g. simple client-server model

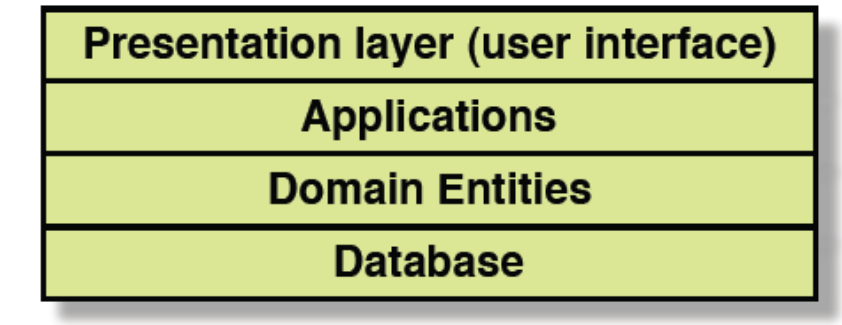


3-layers:

- separate out the business logic
  - helps to make both user interface and database layers modifiable

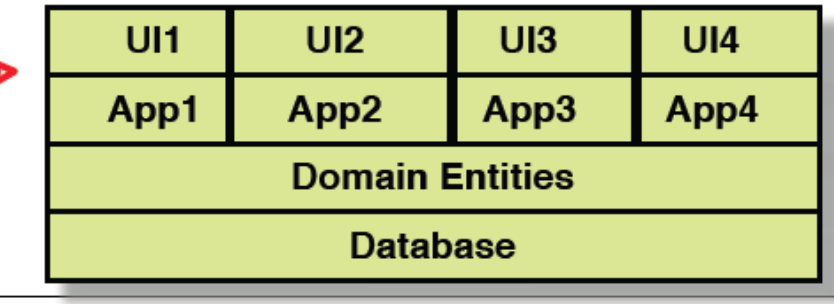
4-layers:

- Separates applications from the domain entities that they use:
  - boundary classes in presentation layer
  - control classes in application layer
  - entity classes in domain layer



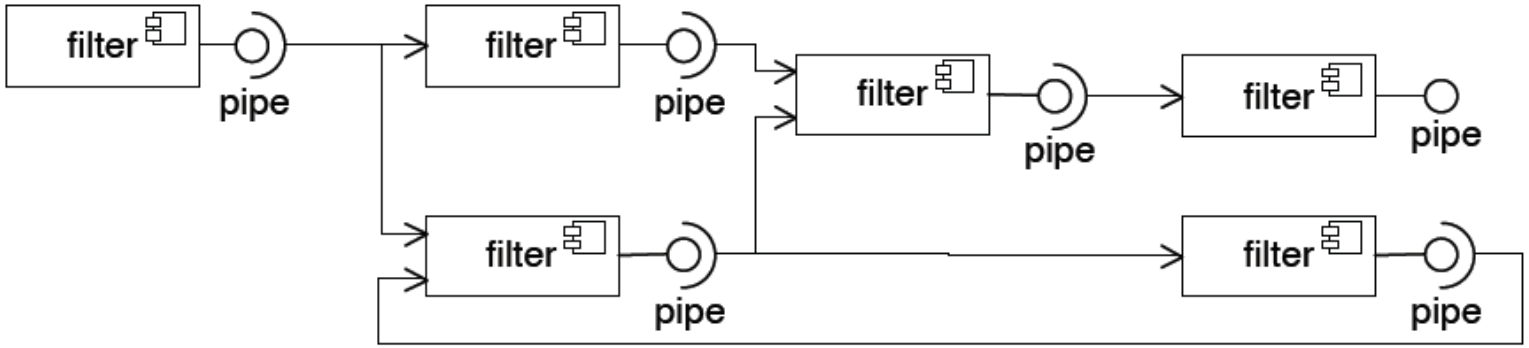
Partitioned 4-layers

- identify separate applications



Pipe-and-filter

Source: Adapted from Shaw & Garlan 1996, p21-2. See also van Vliet, 1999 Pp266-7 and p279



Examples:

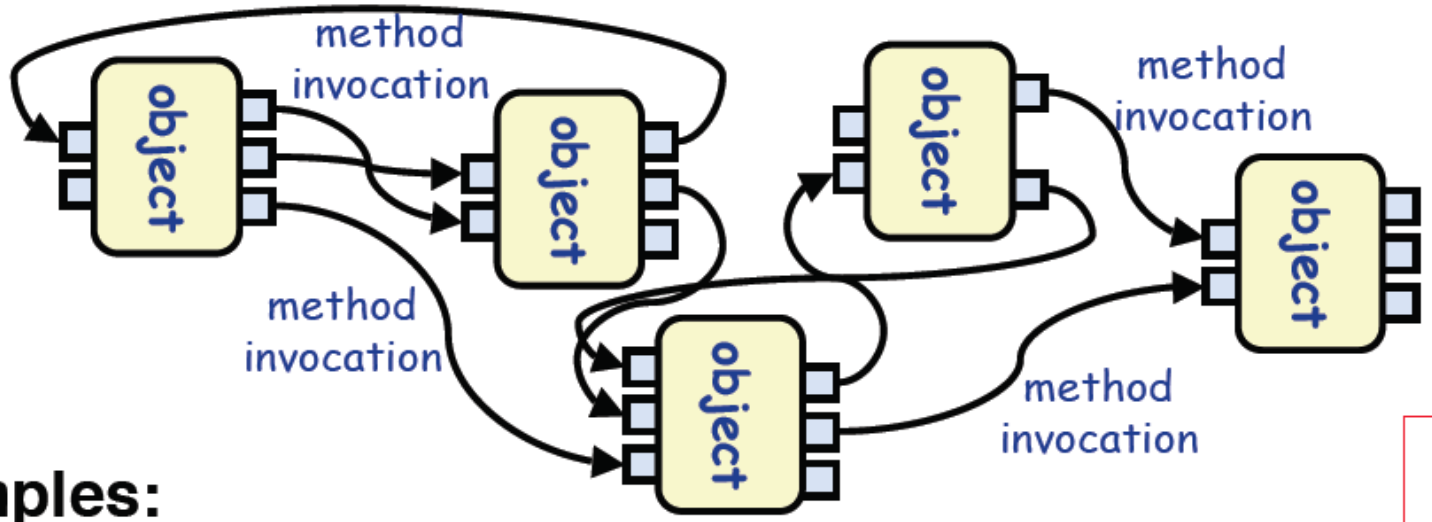
- UNIX shell commands
- Compilers:
  - Lexical Analysis -> parsing -> semantic analysis -> code generation
- Signal Processing

Interesting properties:

- filters don't need to know anything about what they are connected to
- filters can be implemented in parallel
- behaviour of the system is the composition of behaviour of the filters
  - specialized analysis such as throughput and deadlock analysis is possible

Object Oriented Architectures

Source: Adapted from Shaw & Garlan 1996, p22-3.



Examples:

- abstract data types

Interesting properties

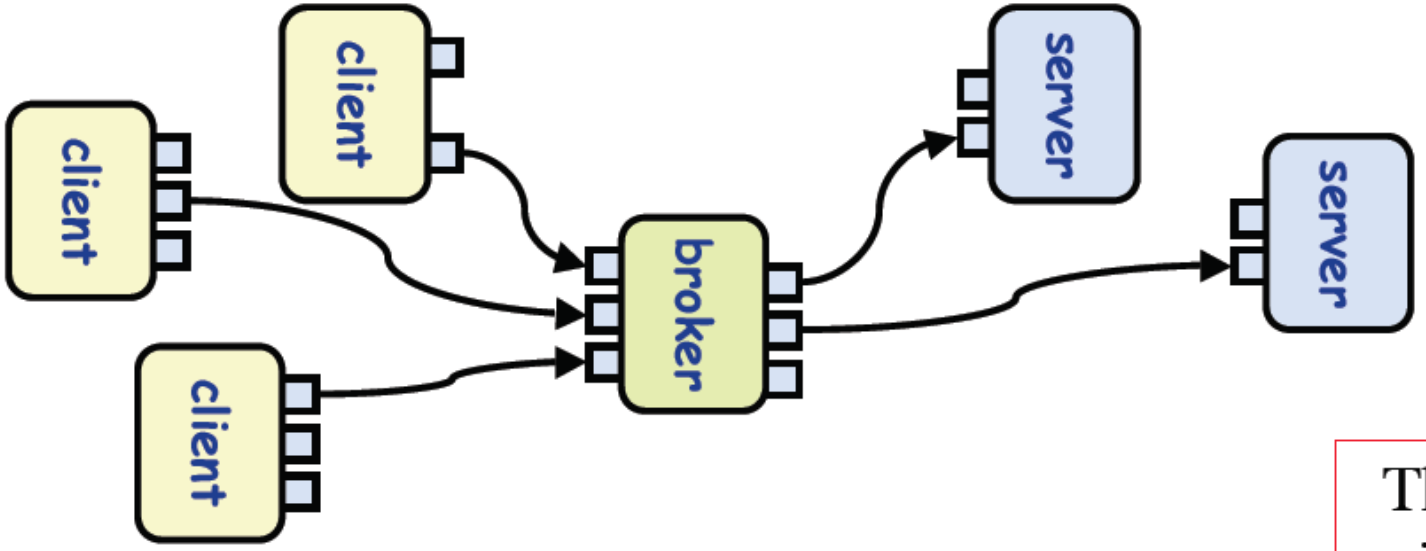
- data hiding (internal data representations are not visible to clients)
- can decompose problems into sets of interacting agents
- can be multi-threaded or single thread

Disadvantages

- objects must know the identity of objects they wish to interact with

This is not UML!

Variant: Object Brokers



This is not UML!

Interesting properties

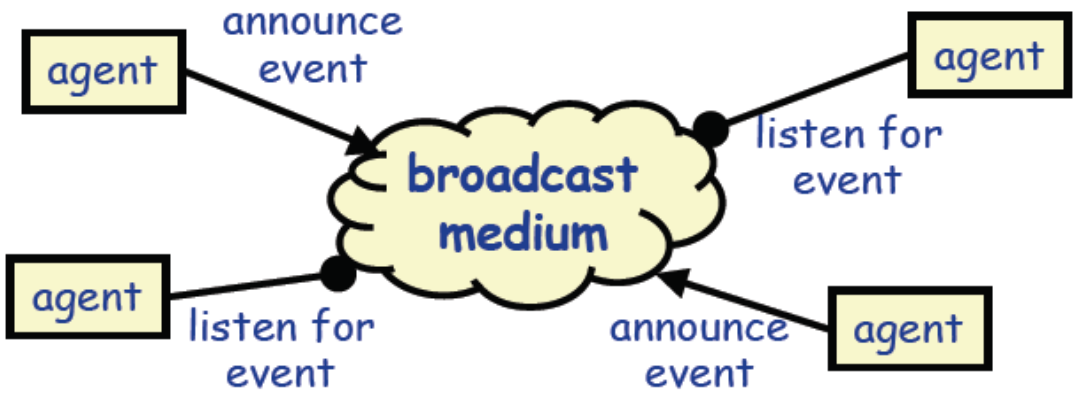
- Adds a broker between the clients and servers
- Clients no longer need to know which server they are using
- Can have many brokers, many servers.

Disadvantages

- Broker can become a bottleneck
- Degraded performance

Event based (implicit invocation)

Source: Adapted from Shaw & Garlan 1996, p23-4. See also van Vliet, 1999 Pp264-5 and p278



This is not UML!

Examples

- debugging systems (listen for particular breakpoints)
- database management systems (for data integrity checking)
- graphical user interfaces

Interesting properties

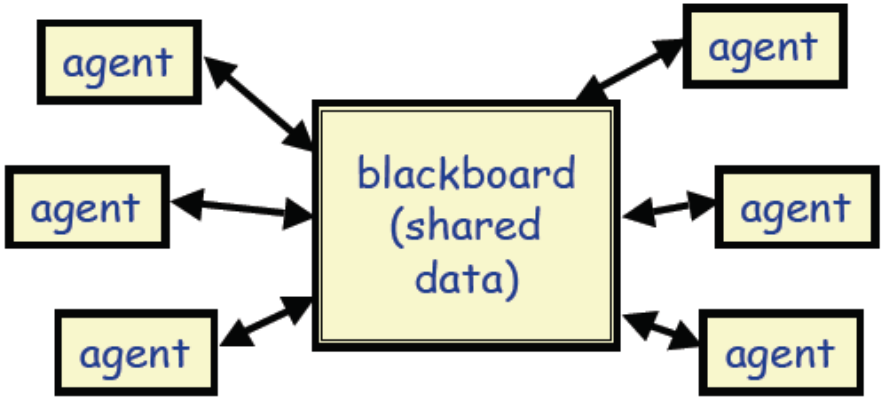
- announcers of events don't need to know who will handle the event
- Supports re-use, and evolution of systems (add new agents easily)

Disadvantages

- Components have no control over ordering of computations

Repositories

Source: Adapted from Shaw & Garlan 1996, p26-7. See also van Vliet, 1999, p280



Examples

- databases
- blackboard expert systems
- programming environments

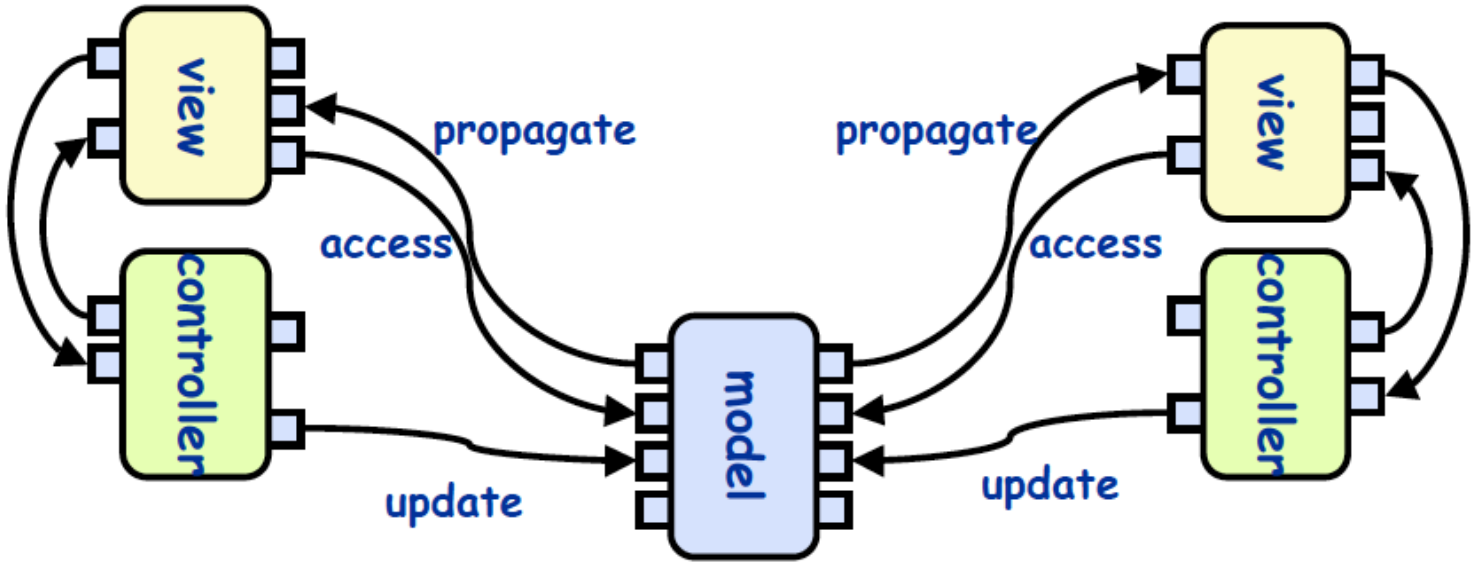
Interesting properties

- can choose where the locus of control is (agents, blackboard, both)
- reduce the need to duplicate complex data

Disadvantages

- blackboard becomes a bottleneck

Variant: Model-View-Controller



Properties

- One central model, many views (viewers)
- Each view has an associated controller
- The controller handles updates from the user of the view
- Changes to the model are propagated to all the views

summary

- avoid unnecessary coupling & cohesion
- if a layered approach, what are the layers? what goes in each
  - following a pattern like MVC, MVP?
- modularize for reusability (well designed public interface)
- uml diagrams for discussing architecture
  - adherence to uml syntax is not the point
  - clearly communicating the architecture is the point

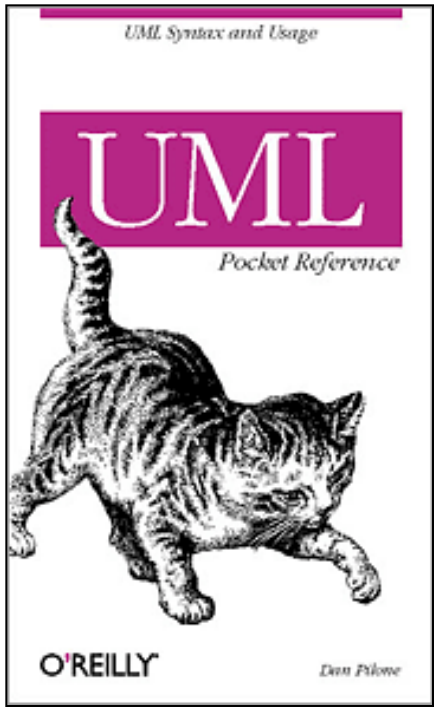
summary (2)

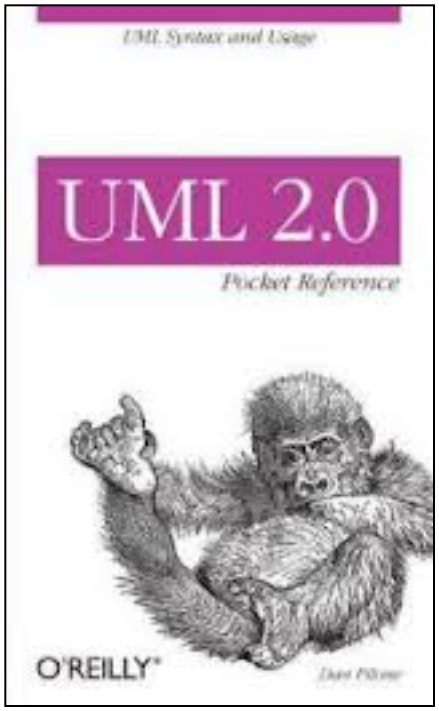
"Il semble que la perfection soit atteinte non quand il n'y a plus rien à ajouter, mais quand il n'y a plus rien à retrancher." – Antoine de Saint Exupéry, Terre des Hommes, 1939

(my) translation: *"perfection is finally attained not when there is no longer anything to add, but when there is no longer anything to take away"*

summary (3)

- tons of uml stuff online, but for those that still like paper books I recommend:





group selection – round 2